Date : 06/15/2016

EIC Detector R&D Progress Report

Project ID: eRD15
Project Name : R&D for a Compton Electron Detector
Period Reported: from 01/15/2016 to 06/15/2016
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Abstract

Precision polarimetry is an important component for the EIC. It aims at reaching 1% level precision. Compton Polarimetry is commonly use for electron polarimetry. It allows a non invasive measurement of the electron polarization. Accuracies up to 0.52% were achieved using the Compton Electron detection. Sub-percent precision is foreseeable for EIC though the significantly higher current and space constraints require an extensive study. This proposal is looking at the option of a semi-conductor detector in a Roman Pot chamber to detect the Compton electrons.

EIC Detector R&D Progress Report

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June 15, 2016

1 Progress Report Section

1.1 Past

1.1.1 What was planned for this period?

Here is the list of task from the previous report :

- Completion of the first pass beamline design of the Compton
- Study of background and detector response.
- Design of the test stand.
- Contact the TOTEM collaboration.

From last report : "The collaboration reported on the preparation of the simulation framework for the Compton polarimeters electron detector in the EIC lattice. The GEMC framework using GEANT4 and developed for CLAS12 at JLab was employed. The design discussed includes a Compton chicane including beam pipe. Testing of the simulation framework has begun, and manpower to pursue the effort has been identified and engaged. The collaboration is taking into account the significant difference in expected rates between the eRHIC and JLEIC designs. The collaborators have made contact with the CLAS12 SVT effort with their local wire bonding expertise with a view towards future studies of timing response of possible detectors including diamond based devices. The Committee takes note of the planned contact with results from existing Compton polarimeters in operation, for example, at JLab and elsewhere. The collaboration plans a revised scattering chamber to enable in-beam tests of candidate detectors, their time response and their electronics. The Committee looks forward to the next report where first simulation results are expected and to the resulting discussion of machine backgrounds and interfaces as well as to a discussion of radiation damage to any sensor and the power deposited in a detector and its infrastructure by backgrounds. An interesting discussion would address required amount of shielding and any limitations on laser power and thus counting rate that may result, and the effect on measurement strategy, time and precision. Continued contact with the accelerator groups developing the two machine reference designs is encouraged."

1.1.2 What was achieved ?

Preliminary design of the test stand was completed. The cost of the lower chamber is more accurately defined and is ready to be built. Contact with Kansas University was very fruitful. Their experience with Roman Pots at LHC and detectors will be very useful for the development of the Compton Polarimeter.

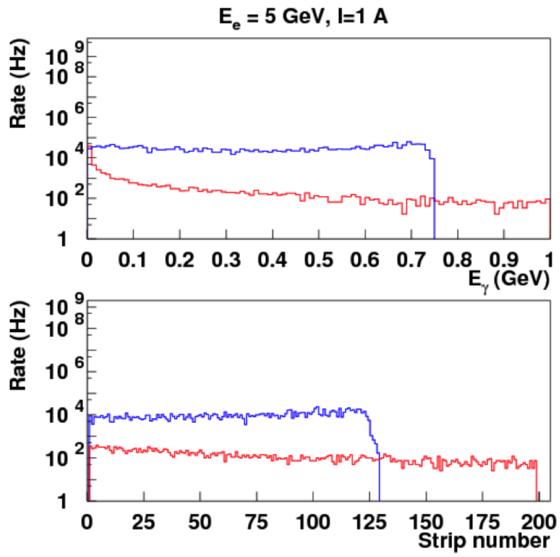

Figure 1: Signal to background for 1A of current and 10W of laser power at 5 GeV. Top: Photon detector; Bottom: Electron detector.

Simulation

GEANT3 simulation for laser studies Over the last several months, we have performed some additional simulations and calculations to determine the optimum laser system for the Compton polarimeter at EIC. There are several issues to consider in choosing the best laser system. These include:

- Rates: Measurements must be able to be made in a reasonable period of time. Given the high beam currents expected at an EIC, this is not a driving concern, but should still be considered.
- Signal to background: This is the primary issue that was addressed in our recent simulations. The high repetition rate of the electron beam means that suppression of backgrounds via low duty cycle pulsed lasers is not practical. On the other hand, the use of high-gain Fabry-Perot (CW) cavities may introduce new backgrounds. It is possible that the optimal system could be a one-pass, CW laser.
- Laser helicity flipping: It is desirable to be able to measure the polarization of the + and − helicity electrons separately. At JLEIC, the two electron spin states are split into two macro-bunches about 3.2 us long, with a time interval of about 350 ns between macro-bunches. It is desirable to be able to flip the laser helicity on a time scale comparable to the macro-bunch separation. Investigation of rapid laser helicity flipping is beyond the scope of this project, but it is worth mentioning that it is likely that it will be easier to quickly flip laser helicity of a one-pass system.

We have performed simulations using GEANT3 to investigate issues 1 and 2 above. To date, these simulations have focused on the backgrounds due to Bremsstrahlung and beam halo in comparison to the Compton scattering process. Figure shows a simulation for the Compton scattering rates compared to the Bremsstrahlung rates for a single-pass, CW laser with 10 W of power. In this case, one can make the laser-electron beam crossing angle rather small (on the order of 0.3 degrees). The beam energy is taken to be 5 GeV with a beam current of 1 A. With a nominal beamline vacuum of 10^{-9} Torr, the signal-to-background is adequate for both the photon detector (top) and electron detector (bottom). This gives us hope that a single pass system will be sufficient however, at this juncture it is prudent to also plan for the possibility of implementing a Fabry-Perot cavity to potentially improve the signal-to-background.

Figure 2 shows an example of the potential problems. Both plots in the figure show the rates due to the Compton scattering process, Bremsstrahlung, and beam halo. In the plot on the left, the apertures associated with the Fabry-Perot cavity are +/- 2cm from the beam (in the vertical dimension), while for the plot on the right the apertures are +/-4cm from the beam.The contribution due to beam halo

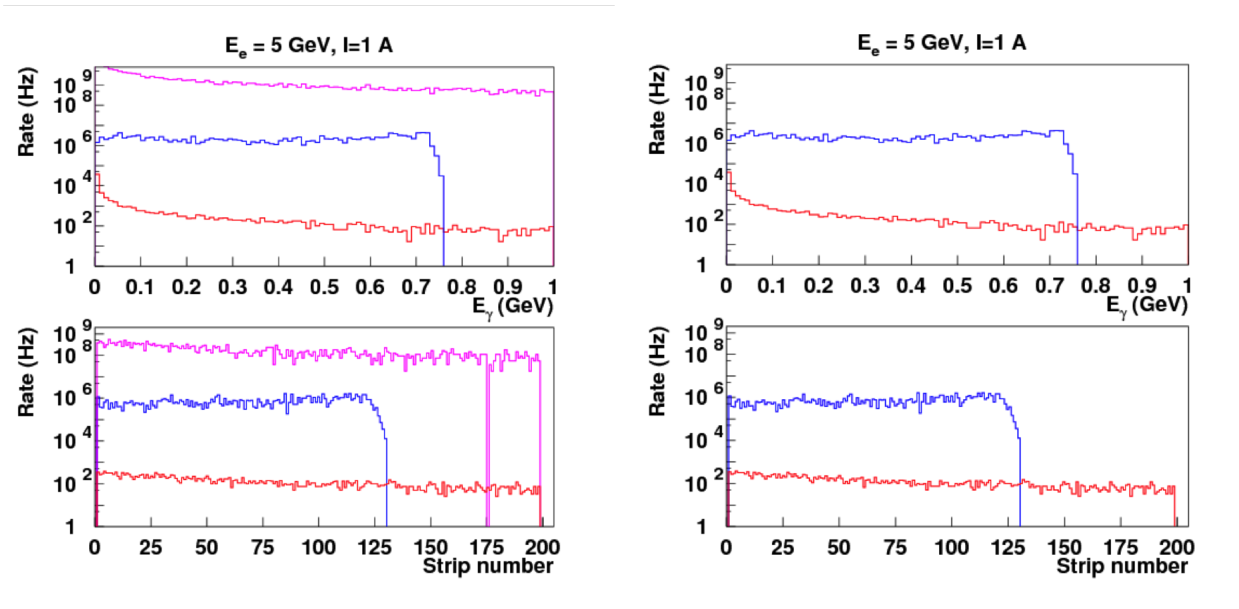

Figure 2: Geant3 simulated rates in the photon detector (top) and electron detector (bottom) for Compton backscattering (blue curve) and Bremsstrahlung (red curve). The beamline vacuum is taken to be 10^{-9} Torr with a beam energy/current of 5 GeV/1 A. The electron detector spectrum is plotted vs. strip number in this case strip 25 corresponds to the zero-crossing of the asymmetry (about 2 cm from the beam for our layout). In the implementation of a Fabry-Perot cavity, care must be taken to not introduce additional backgrounds in the form of the interaction of the beam halo with the additional elements and apertures required for the mirror holders associated with the low-loss mirrors needed for the cavity.

Energy	Current	1 pass laser (10 W)		FP cavity (1 kW)	
(GeV)	(A)	Rate (MHz)	Time (1%)	Rate (MHz)	Time (1%)
3 GeV	3	26.8	161 ms	310	14 ms
5 GeV	3	16.4	106 ms	188	9 ms
10 GeV	0.72	1.8	312 ms	21	27 ms

Table 1: Event rates and measurement times (for 1% statistics) for the single-pass and Fabry-Perot cavity laser options. The rates are adequate for both solutions assuming negligible backgrounds. The CW laser solution assumes a 10 W laser with a crossing angle of 0.3 degrees, while the Fabry-Perot cavity system assumes 1 kW at a crossing angle of 2.6 degrees. A fixed polarization of 87% was assumed for the polarization measurement time calculations. This is not necessarily realistic for all energies, however is appropriate for the order-of-magnitude estimates shown here.

is almost completely absent for the wider aperture. The key point here is that it is important to have some realistic estimate of the beam halo, and carefully design the Fabry-Perot cavity accordingly. It is also worth noting that increasing the aperture for the Fabry-Perot cavity implies that the cavity must be longer to achieve the same beam-laser crossing angle. We have done the simple exercise that shows a stable cavity with a reasonable 2-meter length can be built that will accommodate the +/-4 cm aperture used in our simulations.Figure 2: Simulated rates for different Fabry-Perot cavity geometries. The red and blue curves are as in Figure 1.1.2, while the magenta curves denote the rates due to beam halo interacting with the mirror apertures associated with the Fabry-Perot cavity. For the plot on the left, the apertures are +/-2 cm from the beam, while on the right they are +/-4cm from the beam. The Fabry-Perot cavity is assumed to provide 1kW of CW power at a crossing angle of 2.6 degrees.Finally, we have calculated to absolute rates and measurement times (for a 1% statistical measurement of the polarization) for both the single-pass laser solution shown in Figure 1.1.2 and the Fabry-Perot cavity solution shown in Figure 2 (Table 1). In this case, the rates and times are integrated over the full Compton spectrum and assume that the measurement is made in counting mode (as opposed to energy-integrated mode, for example). These estimates come not from the GEANT3 simulation, but from an analytical calculation of the luminosity and Compton cross section. Also, no backgrounds are included, so measurement times would likely be slightly longer for the real-world scenario.From Table 1 we can see that the rate of Compton backscattered events is greater than 1 MHz for all the energies considered (beam currents associated with this energies are the maximum allowed by the JLEIC design). The associated measurement times are also quite short, on the order of 100-300 ms. If there were no concern for beam-related backgrounds, the single-pass system would be an adequate option with the advantage of simpler implementation. The event rate for the Fabry-Perot cavity laser option is on the order of a factor of 10 larger (even though the power is 100 times larger, some rate is lost due to the larger crossing angle that is required). In conclusion, we have shown that both a single-pass laser and Fabry-Perot cavity-based laser system are both feasible options for the Compton polarimeter at JLEIC. The final choice will likely not be made until the full background simulations using the improved GEANT4 based package are complete.

GEMC (GEANT4) simulation

Beamline geometry The first months of the current project year were dedicated to implementing the beamline geometry as shown on Fig. 3 and Fig. 4. Simple beam pipe is implemented, there is still refinement in the design needed and some work on implementing the magnetic field.

Simulation of background The second step was the study of the background coming from the beam which can be a significant rate in the detector since the electron current can reach up to 3A. Electrons were transported in the chicane and the rates in the electron detector are shown in Figure 5.

Simulation with the Compton Event generator The rest of the time was spent on the event generation and simulation in GEANT4. We reused the event generator from Richard Petti from

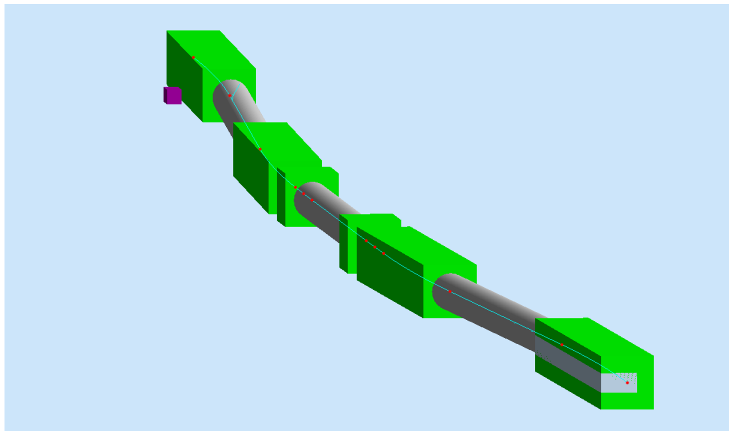

Figure 3: GEMC model of the beamline and of the Compton chicane.

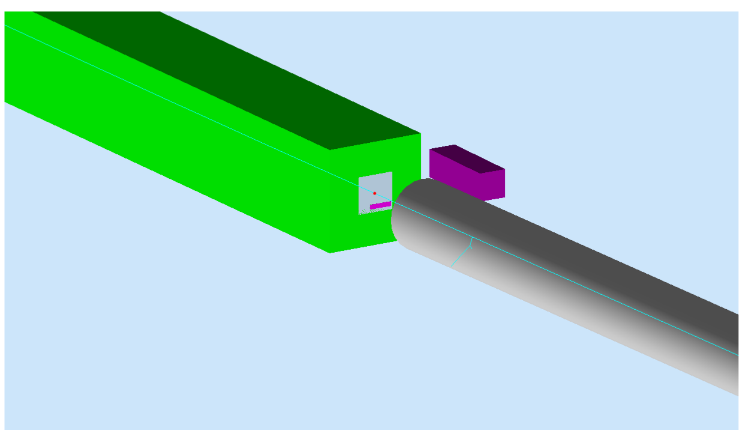

Figure 4: Close-up of the electron detector in front of the fourth dipole – the electrons are momentum analyzed by the third dipole.

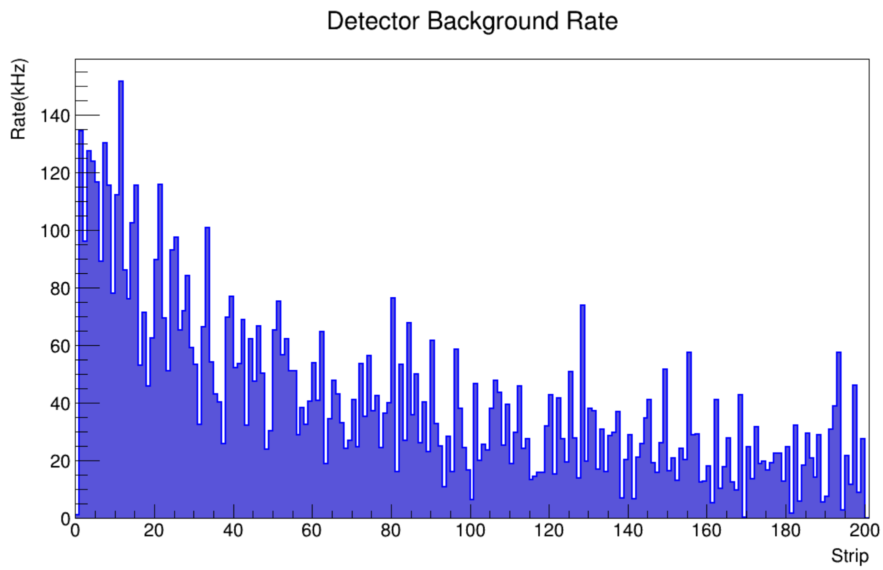

Figure 5: Electron detector rate from the beam-induced background (GEANT4, no beam halo).

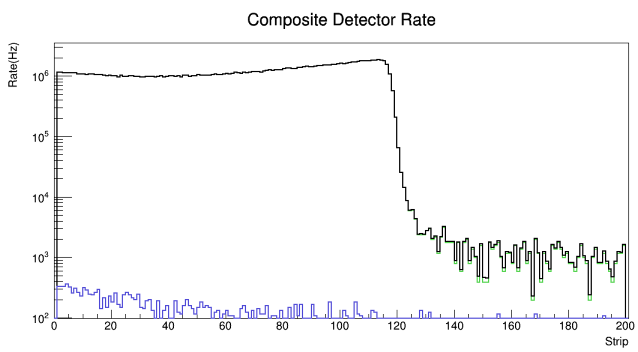

Figure 6: Signal and background in the Compton electron detector (GEANT4 simulation) for 1A of beam and 1 kW of laser power

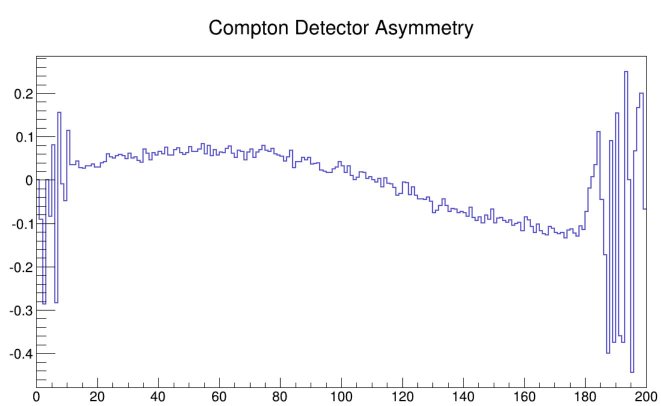

Figure 7: Computed asymmetry from the detector signal.

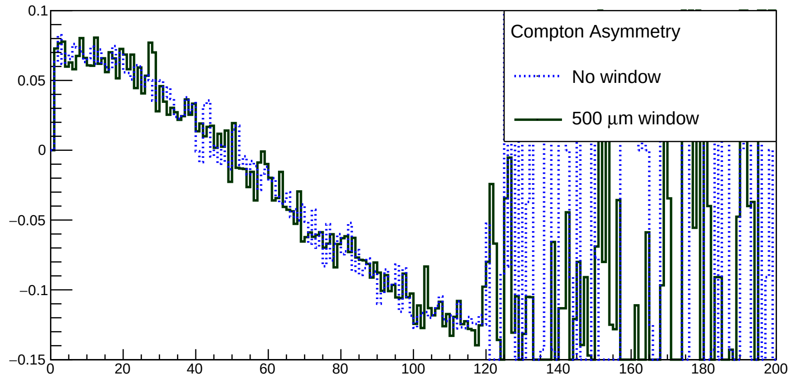

Figure 8: Compton asymmetry with and without a 500 μm thin steel window in front of the detector.

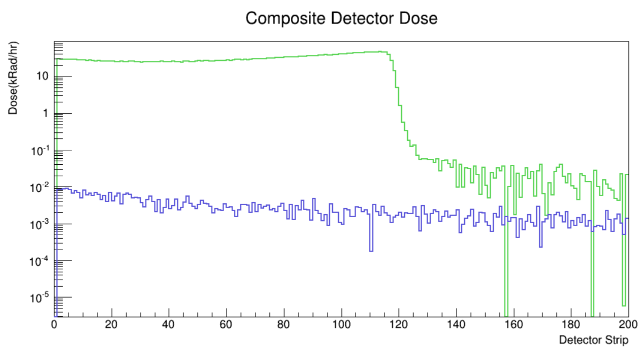

Figure 9: Compton dose deposition per hour.

the eRD12 to generate Compton events. We crosschecked the rates and asymmetry with the Geant3 and theoretical computation. Preliminary results of the expected background and expected signal gives a first idea of the signal to background ratio for this design. The results for signal and background rates in the electron detector with the GEANT4 simulation are shown in Figure 6. The signal to noise is consistent with the GEANT3 simulation and so far not taking into account additionnal background from the beamline and the interaction region, 10 W of laser power is sufficient. The projected Compton asymmetry is shown in Figure 7. An interesting feature of Figure 6. is that there are 'signal electrons' beyond the Compton edge (higher strip number $\Rightarrow$ lower energies). This is the result of a fraction of the Compton scattered electrons rescattering before the detector. This could potentially distort the shape of the asymmetry in Figure 7.

Figure 8 shows the result of our study of the effect of window in front of the electron detector. The Roman Pot thin windows introduces 500 μm of steel in front of the detector. The plot with and without without are similar within statistical fluctuations. Study with higher statistics and with the full polarization extraction analysis will be done to study the incurred systematic error on polarization.

Preliminary dose estimate Since the simulation is running, we computed an estimate of dose deposited (Figure 9). This shows that most of the radiation damage is still coming from the Compton signal and the rest of the radiation is fairly low meaning we can safely leave the detector in place and turn off the laser to have a lower duty cycle. From the running experience from the Hall C QWeak experiment, the diamond detector saw no deterioration of signal after 2 years of running at 180 μA which corresponded to more than 10 Mrad of dose. This corresponds to 570 rad per hour at 180 μA which gives a value of around 10 MRad per hour. The simulation is giving a number of about 90 kRad per hour per strip, which correspond to about 10 MRad per hour for the whole detector which is close to estimated number. More accurate crosschecks and measurements will be done to check the simulation

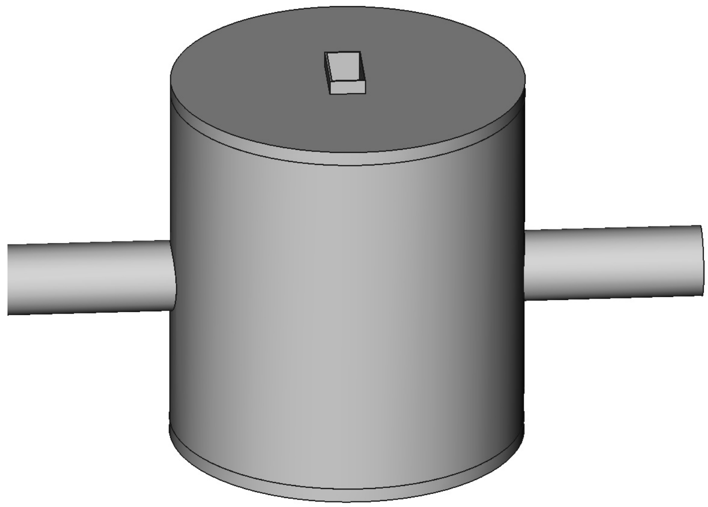

Figure 10: Simple CAD model of Roman Pot

calibration later. Looking at the polarization lifetime of a few hours at the lowest energy and highest current of 3A a polarization measurement every 10 minutes should be sufficient. Measurement can be made more often at the highest energy where polarization lifetime is shorter but beam current will be lower at 0.7 A. A radiation hard detector is desirable and diamond is a good candidate.

Wakefield estimate The Compton electrons are separated from the main beam by up to 7 cm at the location of the detector. In order to have the best systematic errors, we must catch both the zero crossing of the asymmetry and the Compton edge. This well make the detector self-calibrating, and will eliminate many systematics, particularly due to the detector positioning. For most energies it means the detector needs to be one to two centimeter from the beam. For a safe beam operation nothing closer than 3 cm from the beam is advised when beam is being tuned which make the design of a thin window difficult considering how close it would be from the beam. The best compromise is a moving detector which could be inserted close to be beam for the polarization measurement. Such detector is in operation at Jefferson Laboratory though with the expected EIC current (50 mA and up to 3 A) an estimation of the power deposited by the Wakefield from the beam is needed. Since the detector will most likely need to be shielded and to have more flexibility in accessing the detector a Roman Pot design is envisionned for the Compton electron detector. This would be the first time the roman pot technique is being used for an electron beam. We are planning to replicate the same study as it was done for the TOTEM [1] roman pots.

Our collaborators from SLAC have the machinery to study Wakefield Higher Order Modes, though in order to speed up the process of optimization the detector geometry to reduce the impedance of the detector which will require several iterations we also looked at local expertise from the JLab RF group.

A first simple design has been implemented to give a baseline of the RF power deposited. Numbers from the TOTEM collaboration are encouraging since a value of 10 W was reached but the study needs to be redone with the beam structure of JLEIC (476 MHz). For PEPII which had a smaller bunch length values up to 2 kW were reached for some of the collimators. The model could be imported to CST Particle Studio, available at JLab. Preliminary results will be presented at the next report.

1.2 Vacuum chamber

The goal of the test stand is to make the current Hall A and C Compton polarimeters compatible with new detectors for testing potential candidates for the EIC Compton electron detector while also being compatible with the existing detectors in Hall A and Hall C. This will enable testing of existing silicon and diamond detectors, as well as new detectors and electronics, which could be carried out in either hall,

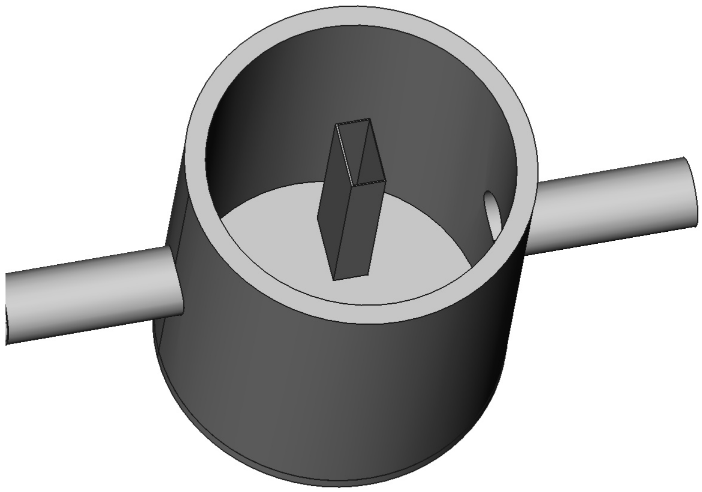

Figure 11: Simple CAD model of Roman Pot inside view

improving the availability of the setup. The Jefferson Laboratory Compton polarimeters have already been proven to be capable of providing polarization measurement at the 1% level, this will be a way to benchmark the performance of the detector. The design of the test stand is based on the Hall C electron detector design which was used successfully for the diamond detector. A preliminary design of the chamber was done to get a cost estimate which is close to the requested number last year.

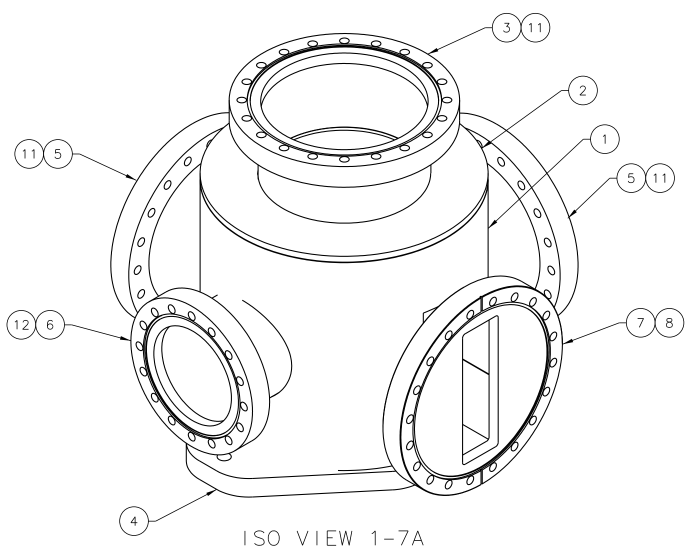

Figure 12: Design of lower chamber

1.2.1 What was not achieved, why not, and what will be done to correct ?

We ran out of time to completely address all the requests from the last committee report, we are still working on checking the normalization and optimizing the event generator for more efficient simulation.

- Study of effect of bunch interacting with same bunch or different bunch is on hold waiting for results of the beam simulation (currently underway at ODU). Preliminary result of the possibility of different numbers of electron and ions bunches should be available by the end of 2016
- Background from the IR was not done yet mostly due to computing power and running the different physics process of the IR
- Study of the systematics will be done after the polarization extraction analysis is implemented
- Synchrotron radiation
- Wakefield power deposition in detector

A few technical items where we lost time :

- The study of the photon detector response to crosscheck with the old Geant3 simulation but contrary to electrons the primary particle is lost for a photon and handling of the secondaries to determine energy deposit was not clear. This is better documented in the Monte Carlo documentation.
- A study to improve the Bremsstrahlung efficiency generation was done, typically one can scale the air pressure in the beam pipe to generate more Bremsstrahlung event, though the study showed that going above atmospheric pressure was giving rates non linear with the pressure most likely due to other processes.
- The option to add custom physics list to GEMC needs to be developed.

We expect the studies to go faster now that the postdoc (Joshua Hoskins) is set up and familiar with the simulation and data analysis and that results were crosschecked with the GEANT3 simulation. The main issue is to run the full setup in the simulation on the JLab batch-farm to produce high statistics Up to now to make rapid progress the simulations were done only with the Compton chicane part.

Complete design of the chamber was not completed due to lack of designer time this year due to experimental schedule constraints, the money allotted will be carried over and used next year. Availability of the designer next year was agreed upon.

The option to test the detector with the CLAS12 preamp was discussed but it is postponed to next year due to time constraints to complete the CLAS12 Silicon Vertex Tracker this year.

1.3 Future

1.3.1 What is planned for the next funding cycle and beyond ? How, if at all, is this planning different from the original plan ?

For next funding cycle we are planning to continue the simulation work to have numbers on the signal to noise background and expected accuracy from the detector with a more realistic setup. We will implement the current electron detector analysis software to study the systematics introduced on the polarimetry measurement. Estimates for power and radiation damage will be evaluated after we cross check the normalization of the simulation. Model of the halo of the beam will be added to evaluate the contribution of this background. Bench test of the TOTEM electronics will be done to determine if the detector or electronics is the main limitation to a short pulse width, the TOTEM detectors seem to fullfill the timing requirements, the main developement will be how to handle the Compton trigger rates. This will be more developed in the proposal section. The lower chamber will be sent to be built and will be used as shielding for the bench tests. The design of the top chamber will be finalized to be procured at the next funding cycle, we would like to carry the previous funding to the following year.

1.3.2 What are the critical issues ?

The main critical issues to be addresses by this proposal :

- determine the signal to background expected on which depends the choice of the photon source and detector
- have a preliminary design for the beamline for the JLEIC design based on Roman Pot. After discussion the eRHIC people it seems this design might also work for eRHIC but is more difficult than for protons and would need to be studied in depth. The current option for eRHIC is an exit window which might be easier to implement than in the JLEIC design due to different magnet configurations.
- obtain a detector with a timing response faster than 100 ns, to be able to separate the different sources of eRHIC in the case the ring linac design

- have simulation and analysis to estimate the expected accuracy of polarization measurement for a given design
- determine if background from IR is an issue for the JLEIC design where the polarimeter is placed after the IR
- develop a beam test stand in the current subpercent capabable Compton Polarimeter to prove that the chosen detector reaches the needed specifications and does not introduce systematics preventing to reach 1% accuracy level.

1.4 Manpower

Manpower estimates for 2016

Personnel	% FTE	location	tasks
Alexandre Camsonne	20	JLab	General organization,Wakefield studies, postdoc supervision
David Gaskell	5	JLab	Geant3, Laser system, postdoc supervision
Joshua Hoskins	50	JLab	GEMC simulation and data analysis

Planned manpower for 2017. We are welcoming the Kansas University group to help on the electronics and detector.

Personnel	% FTE	location	tasks
Alexandre Camsonne	20	JLab	General organization,Wakefield studies, postdoc supervision
David Gaskell	5	JLab	Geant3, Laser system, postdoc supervision
Joshua Hoskins	50	JLab	GEMC simulation and data analysis
Michael J. Murray	5	Kansas University	detector, electronics
Christophe Royon	5	Kansas University	detector, electronics
Nicola Minafra	5	Kansas University	Wakefield and amplifier design

In addition to the core manpower, Michael Sullivan from SLAC is advising on Synchrotron Radiation, Robert Rimmer and Haipeng Wang from JLab RF group are advising about Wakefield HOM modelling.

1.5 External funding

None

1.6 Publications

The work on the EIC R&D Compton Electron Detector was presented at the POETIC 6 conference and a proceeding was published.

2 Proposal

2.1 Proposal deliverables

This year proposal is planning to complete the studies started in the first year.

- implement simulation on the farm and run with the full detector setup to determine background in the detector from the interaction point
- complete beamline pipe in simulation to look a background contribution from the pipe
- implement beam halo in simulation
- implement polarization analysis and study the systematics
- complete the wakefield simulation to have a first estimate of the power deposit in the detector to determine if Roman Pot design is doable for the electron side
- study of synchrotron radiation effect in the detector
- reduce background and protect detector through shielding
- study of effect of shielding on measurement
- show TOTEM detector can reach less than 100 ns pulse width making it compatible with eRHIC beam structure

- design of multichannel amplifier to amplify diamond or silicon signal possibly on the detector
- design of multichannel discriminator board for readout of all the detector channels
- complete design of test stand for beam test

3 Simulation and modeling

3.1 Beam halo implementation for background study

The next step is to look at the background contribution from halo. We will be using a double gaussian distribution as described in the PEPII report:

$$\frac{dN}{dxdy} = e^{-\frac{x^2}{2\sigma_x^2}-\frac{y^2}{2\sigma_y^2}} + Ae^{-\frac{x^2}{2(S_x\sigma_x)^2}-\frac{y^2}{2(S_y\sigma_y)^2}} \tag{1}$$

This background can be significant, especially when there are close apertures that could be needed if an optical cavity is used.

Task	Time estimate
Implement Halo	1 month
Simulation full setup	2 month
Implement analysis	1 month
Study of systematics and background	6 months

3.2 Analysis

We have analysis code that were used for polarimetry measurement during the QWeak experiment [2]. We will get the analysis scripts and adapt to the EIC simulation to extract a polarization from pseudo data. It consists in fitting the measured asymmetry with the theoretical analysing power to extract the polarization.

3.3 Wakefield Evaluation and Roman Pot Design

First result from the simple design will be generated to determine if the roman pot option is reasonable in first approximation. A more realistic design of the roman pot will be done to optimize the impedance. A few design iterations and CST simulation will be needed. The power spectrum of JLEIC and impedance of the setup needs to be simulated to give the first evaluation of the power deposit in the detector. This work will be done in collaboration with the Kansas University group and the JLab SRF group. Once power from wakefield is determined modelling in ANSY can be done to determine the heat distribution and design the cooling.

3.4 Synchrotron radiation estimation

Even if the Compton Electron Detector is in a favorable position compared to the photon detector, at 3 A of beam current synchrotron radiation will be an issue and needs to be studied. Synchrotron radiation can results in electrons from the beam going into the detector and of photons hitting the detector directly or after reflections. Michael Sullivan from SLAC has experience with the PEPII and will help in evaluating the synchrotron radiation for the electron detector and way to mitigate them using shielding and absorbers. He will be visiting at the end of June. This study will be completed in the next year crosschecking the simulation results analytic formulas.

4 Test stand

4.1 Vacuum chamber

Design of the top chamber will be completed after the front end is designed to take into account the space taken by the new electronics and the use of the connectors matching the electronics. Designer time has been allocated at JLab.

4.2 Bench detector test

4.2.1 Electronics

We would like to start the experimental work on the detector and electronics by setting up a detector test bench at Jefferson Laboratory. This will be the starting point of the future beam tests which will use the same electronics.

CIVIDEC amplifier The TOTEM experiment is using the CIVIDEC C6 Fast Charge Amplifier. This single channel amplifier was demonstrated to work with the TOTEM diamond detector. It will be useful to look at signals directly and to be used as a baseline performance for the development of a custom amplifier. We are planning to procure 2 channels of amplifier each channel is about 3.6 K$ for a total 7.2 K$.

Custom amplifier With the help of Kansas University, we will develop an amplifier tailored for the detector, which could be located on the detector or closer to the electronics. This will serve as base for a future multichannel amplifier which could be turned into an ASIC. The TOTEM solution is very likely to satify the eRHIC requirement but a lower cost option with a multichannel preamplifier will be studied for this proposal that could be used for the final setup. A total of 768 channels is needed. A budget of 20 K$ is allotted for this development.

SAMPIC sampling electronics The SAMPIC system is a analog sampling chip used by the TOTEM experiment developed by the IRFU/CEA Saclay electronics group. It allows to sample from 3 to 10.2 GHz for 16 channels with a depth of 64 cells. By recording the whole waveform of the detector signal one can determine the timing resolution and width of the pulse similarly to having all the channels on digital oscilloscope. Given the low cost per channel we will procure a SAMPIC system for studying the pulse shape of the detectors with cosmics, sources and later beam. One module is 4.2 K$ for 32 channels.

Development of a Discriminator Assuming the preamplifier is working, the detector signal will be fed to an ASIC based discriminator to reduce the footprint of the current electronics and reduce the capacitance from the PCB length. This will also simplify the integration of the total 768 channels. For the Compton polarimetry measurement The VMM3 chip will be used if available otherwise the MAROC chip will be used, both have 64 channels with a discriminator on each channel. This would reduce the footpring of the discriminator part to 3 ASICs for each 192 channels planes. A budget of 20 K$ is allotted to procure and make a prototype board.

4.2.2 Detectors

We will first start to setup a bench for detector testing to have a baseline of the performance of our current existing detectors in term of timing and efficiency. The Hall A detector has 4 planes of 192 strips of 500 μm of silicon detector, we have 4 spares that can be used for testing on the bench to evaluate the timing properties of standard silicon. The Hall C detector has 4 planes of 96 strips of 500 μm of diamond detector. Typical silicon detectors have a shaping time of the order of a few hundreds of nanoseconds which is not sufficient for the eRHIC beam structure in the case of several electron sources. The TOTEM experiment is using diamond detector 500 μm thick and thin silicon with thicknesses up to 50 μm thick to improve the timing resolution of the detector. From the simulation, a diamond pulse could be as short as 10 ns. We are planning to test one of the detector and to optimize the shaping and readout to insure good efficiency. The goal of the proposal is to prove we can obtain width shorter than 100 ns will be demonstrated on the bench at Jefferson Laboratory on sample detectors using radioactive sources and cosmics to prepare for a beam test the following year with real minimum ionizing Compton electrons. A final polarization measurement will be foreseen with a multistrip detector fully instrumented.

4.2.3 Timeline electronics and detector test

5 Budget

Following is the requested budget in order or priority (highest first).

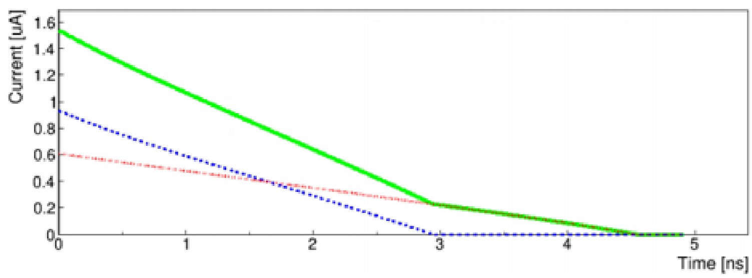

Figure 4.4: *Signal produced by a MIP passing through a* 500 μm *diamond simulated using Weightfield2 [67]. The red dotted line represents electrons, the blue dashed line is for holes and the green solid line is the sum of the two contributions.*

Figure 13: Simulation of the signal response of a diamond detector

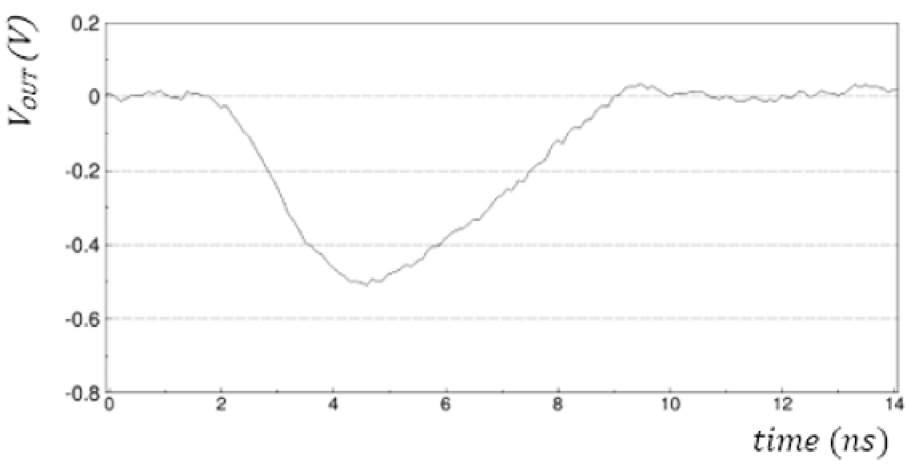

Figure 14: Diamond recorded pulse

Task	Time estimate
Setup	3 month
Pulse measurement	1 month
Developement discriminator	3 month
Developement amplifer	6 monts

Table 2: Timeline electronics and detector test

Allocation	Amount (K$)	Amount with overhead (K$)	Cumulative (K$)
Postdoc	22	33.99	33.99
Travel	15	23.175	57.165
CIVIDEC	3.6	11.124	62.727
SAMPIC	4.2	6.489	79.216
Amplifier design	20	30.9	100.116
TOTEM Si detector	2	3.1	103.206
TOTEM Diamond	3	4.6	107.841
Wirebonding	5	7.725	115.566
Discriminator design	20	30.9	146.466
Vacuum chamber	7	11	161.916
Detector holder	7.5	11.6	173.5035
Test flange	5	7.725	181.2285
Total	117.3 K$	181.229 K$	

Table 3: 2017 Budget request. This list is prioritized, with the highest priority items at the top.

- We request to continue funding for the postdoc to complete the different studies with high statistics and start opimtizing the design and also start the hardware part for the electronics test bench. The base salary for 50 % is 22 K$. The travel budget was increased will also allow to Kansas University people to participate in the setup of the test stand at JLab greatly speeding up its readiness thanks to their experience and we would like to bring Nicola Minafra Kansas University postdoctoral research associate who worked on the TOTEM Roman Pots impedance studies who is located at CERN to help with the Wakefield studies and amplifier design.

  Our minimum budget request is 37 K$.
- We would like to start the experimental work and want to procure 1 CIVIDEC amplifier for a unit cost of 3.6 K$. This will allow to look at the pulse width of the different detectors.
- A 32 channels SAMPIC readout will be procured to be able to study up to 32 channels of detectors at a time and determine the ultimate timing resolution of the detectors. This would be an additionnal 8 K$ of equipement
- Given the cost and size of the CIVIDEC amplifier and since we require 768 channels, we will develop a custom preamplifier which will serve as base for a multichannel preamplifier. We will be dedicating 20 K$ for this task.
- One diamond and on silicon TOTEM detectors will be procured to compare the TOTEM detectors performances with the current Jefferson Laboratory detectors for 10K$.
- And finally parts of the future beam test stand will be ordered : a multichannel discriminator board based on an ASIC will be designed for 20 K$and the lower chamber with a detector holder and a top test flange would be build for 42.5 K$.

All costs have to include the standard overhead of 54.5%, to summarize the minimum budget requested is 52.53 K$. To start the test bench would come to 69.216 K$. Developement of the amplifier and procurement of TOTEM detectors would add up to 115.566 K$. Part of the chamber and electronics design for the actual beam test would add up to 181.229 K$

References

[1] Minafra, Nicola, Development of a timing detector for the TOTEM experiment at the, LHC CERN-THESIS-2016-016, http://cds.cern.ch/record/2139815?ln=en

[2] Amrendra Narayan, Determination of electron beam polarization using electron detector in Compton polarimeter with less than 1% statistical and systematic uncertainty
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